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Use of STEAM Approaches in K-12 Education: A Review

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Abstract: STEAM education is growing in prominence as a competency-based framework that provides K-12 students with essential 21st-century skills. Although the article has a theoretical basis, there are notable loopholes in understanding its practical implementation and in evaluating intricate skills development. This review summarises contemporary evidence on the application of STEAM in K-12 education, based on 16 peer-reviewed works published between 2018 and 2025 in ERIC. This investigates two main research questions: (i) how the theoretical foundation of STEAM is translated into practical pedagogy, and (ii) the status of challenges related to assessment and skill development. The findings suggest that the theoretical basis of STEAM is predominantly enacted through integrated, inquiry-based approaches, especially through Project-Based Learning (PBL) and Design Thinking (DT), alongside Arts integration for creative visualisation and iterative problem-solving. These pedagogies help the students to develop creativity, collaboration, and metacognition. The review outlines several challenges to the sustainable adoption of interdisciplinary practices. It includes the inequitable distribution of teachers trained in interdisciplinary practices and the lack of appropriate tools to assess process-oriented skills. There is a need to invest in teacher development and to adapt assessment strategies to align with new STEAM teaching approaches.

Keywords: *STEAM education, K–12 learning, interdisciplinary pedagogy, creativity, collaboration*

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1. Introduction

Educational activities in K-12 schooling have shown the remarkable popularity of interdisciplinary and transdisciplinary education reform worldwide (Khan, 2024). In educational research, greater emphasis is placed on creativity and collaboration, as these competencies provide a strong foundation for STEAM education. STEAM education is an interdisciplinary model that combines Science, Technology, Engineering, Arts, and Mathematics to support holistic learning (Andriyani, 2024). Education systems are supposed to be more pragmatic and build 21st-century skills (Pant et al, 2024). It makes the educational process more student-centred, engaging, and relevant to the real world beyond the classroom. In Nepal, where formal education relies on memorisation and standardised testing, the development of such skills challenges established traditions and advances national agendas for skill-based education.

STEAM education can be a major step towards implementing an educational system that respects diversity. As a matter of fact, the world today is witnessing increasing pressure on individuals who are not just learned but also better equipped with innovation, flexibility, and the capability to collaborate to resolve tricky and complex issues (Caligiuri, 2025). This triggered a shift in the education paradigm from traditional education to the constructivist, student centered educational paradigm 4Cs: Critical Thinking, Creativity, Collaboration, and Communication (Colodeeva, 2024). Such STEAM educator competencies connect theory with practice in shaping classroom practices to transform the educational practices of the organization. This increases exposure to various intelligences and adopts a pluralisation of teaching in K-12 classroom settings.

The theoretical emphasis of STEAM education in K-12 curriculum frameworks is rooted in student-centered, competency-based, and interdisciplinary learning theories (Mohd Saad et al., 2023), which imply that students learn best when engaged in activities, interacting with others, having real experiences and by using varied strategies of instruction (Eison, 2010; Lin & Tsai, 2021). The beneficial educational theories are operationalised within pedagogical frameworks such as Project-Based Learning (PBL), Design Thinking (DT), and Design Challenges, which are key concepts in STEAM education that supports overall student development and real-world readiness. PBL promotes interdisciplinary knowledge and collaborative long-term investigation of complex real-world challenges. Similarly, Design Thinking provides a structured, iterative, and team-based framework for empathy, problem definition, ideation, prototyping, and testing to systematically improve and innovate ideas.

Incorporating the Arts into STEM fields is the philosophy of STEAM. It is a lot more than just adding an 'A', it is more about inciting a change. Students can look at problems in different, more unique ways. The encouragement of divergent thinking is due to the support for technology and engineering, Aesthetic design, and personal expression (Andriyani, 2024). The purpose of this interdisciplinary blend is to foster an environment in which students could develop the technical skills necessary to construct solutions, along with artistic and creative thinking to present them in an imagined format. Pant et al. (2024) note that STEAM is becoming widespread in education as an alternative to more traditional types of teaching and a dynamic way to train students into creative and critical thinking. Finally, STEAM education aims to equip students at the school level with the collaborative and creative skills needed to navigate an uncertain future.

The 21st-century economy values innovation, complex problem-solving, and transdisciplinary skills, which consequently brought about a global transformation in learning, shifting it towards STEAM education (Milligan, 2023). In this paradigm, experiential, inquiry-based teaching and learning methodologies are preferred, as they are believed to develop the creativity and critical thinking required to address novel societal and technological challenges (Nord Anglia Education, 2020). Such systems prevent students from applying the concepts they learn in the real world and limit their creativity (Adhikari, 2023; Pant et al., 2024). In Nepal, inclusive education is of utmost importance owing to the country's wide diversity and rich culture. The STEAM pedagogy is required to build a solid sense of belonging, applied life-skills, and equip students to play a role in the national development (Impact Hub Kathmandu, 2024).

The policies aimed at developing interdisciplinary/transdisciplinary competencies are important in the promotion of STEAM. However, above all, an effective STEAM policy should guide the implementation of teaching practices that center on competencies such as creative problem-solving, collaborative design, and computational thinking (Carter et al., 2021; Bertrand & Namukasa, 2020). In Nepal, this adjustment is quite recent, but the changes are already taking place. The National Curriculum Framework has started to support the development of integrated and applied learning (Pant et al., 2024). National Innovation Center and Impact Hub Kathmandu are now providing innovative teacher and student workshops that blend STEAM education and local and global competencies (Belbase, 2019; Koirala & Neupane, 2023). The interaction of these changes in policy and practice demonstrates a strong consent that STEAM education is vital. It equips Nepal's youth to contribute meaningfully to the contemporary globalized world and strengthen national growth.

Educational systems in Nepal are being reformed to accommodate STEAM skills that meet both local and global market needs (Maya, 2025). The research provides educational stakeholders with empirical evidence on STEAM educational innovation. This evidence contributes to national school reforms and responds to global trends in education. The results demonstrate how STEAM practices can be used to address current gaps in pedagogical processes, curriculum and the growth of skills. They are also characterized by the increasing demand of interdisciplinary learning environments that equip students with the ability to fit in the fast-changing labor markets (Reaves, 2019). In general, the study draws attention to the importance of aligning Nepal's educational transformation with international standards while ensuring significance to national priorities. The purpose of this review is to synthesize the existing literature on how STEAM approaches improve collaboration and creativity skills among school-level students by investigating reported effectiveness, challenges encountered during implementation and refined best practices. The paper analyzed how integrated STEAM pedagogies had been employed in school education and how they contributed to nurturing students' creativity and collaborative capacities.

2. Methodology

This study employed a literature review-based research design, adopting a traditional thematic review to develop a knowledge synthesis of current studies on the use of STEAM approaches in K-12 education. The review adopted a set of principles to reduce bias and enhance the validity of findings. The steps included a multi-step process of identification, screening, eligibility assessment, and inclusion, coupled with a qualitative thematic synthesis of the studies that would be included.

2.1. Search strategy and data source

Since there have been no previous literature reviews on the use of STEAM in education practice and challenges from 2018 to 2025, this study limited the literature search to English-language references from 2018 to 2025 to gain an understanding of the use of STEAM in education practice and challenges.

Since there have been no previous literature reviews on the use of STEAM in education practice and challenges from 2018 to 2025, this study limited the literature search to English-language references from 2018 to 2025 to gain an understanding of the use of STEAM in education practice. The search strategy employed Boolean operators to combine keywords and achieve more defined, precise results. The keywords "STEAM education AND creativity" were defined, and alternative keywords were used with the OR operator "problem-based learning" OR "project-based learning" to obtain more results. The NOT operators were used to exclude literature focused on higher education, thereby narrowing the search to K-12 education literature.

The search strategy focused on locating peer-reviewed articles and book chapters, then the phrases “steam education” along with the keywords “collaboration, “creativity, “problem-based learning, “project-based learning,” “art-based pedagogy,” and “interdisciplinary learning” at the school level were included. The academic databases of reputation deployed in retrieving the relevant literature include the Educational Resources Information Center, ERIC. The studies were drawn from various international contexts that have ensured diverse perspectives on the implementation of STEAM education, including the United States, Cyprus, Taiwan, Indonesia, Portugal, Jordan, and Greece.

2.2. Review Selection Process

In the current work, a selective process was conducted to ensure relevance and accuracy, as demonstrated with a flowchart (Figure 1). The first step was a basic search in multiple databases, which returned multiple sources. The first step in screening articles was an evaluation of their titles and abstracts to assess relevance to the questions: STEAM education, collaboration, and creativity. A predefined set of inclusion criteria was used to evaluate the full texts of shortlisted documents during the eligibility stage. These criteria required the studies to clearly discuss the implementation of a STEAM approach in a school-level (K-12) educational setting, investigate or report on outcomes related to student collaboration and/or creativity skills and be published as peer-reviewed journal articles. Finally, in the inclusion phase, articles that met all the eligibility criteria were selected for synthesis, while those deemed irrelevant to the specific focus on STEAM approaches, such as “student creativity” and “student collaboration” in research, were excluded. From an initial pool of identified literature, 16 studies were chosen for in-depth review and thematic analysis based on their direct relevance to the research focus. The selection process is summarized in Figure 1.

After conducting a search of ERIC, using only 16 studies for this study is an anticipated and methodologically justified approach, given exclusion and saturation. As saturation continues, research from additional studies remains constant, and further exclusion is justified by evidence that saturation only retrieves previously gathered evidence (Page et al., 2021). The more specific educational subfield achieved literary saturation on multiple occasions, with the core set of studies highly relevant to previously published work. This is because new studies tend to lack methodological quality and address research questions that fall outside the specific aims of the review (Snyder, 2019). The studies that focused more on methodological exclusion, along with those with less detail on quality and a lack of rigor guiding the research, further evidence that saturation has been achieved (Grant & Booth, 2009). As such, the 16 studies in this case provide stronger evidence of quality-focused research and are more a compilation of evidence strongly relevant to the case than a result of limitations in the search process.

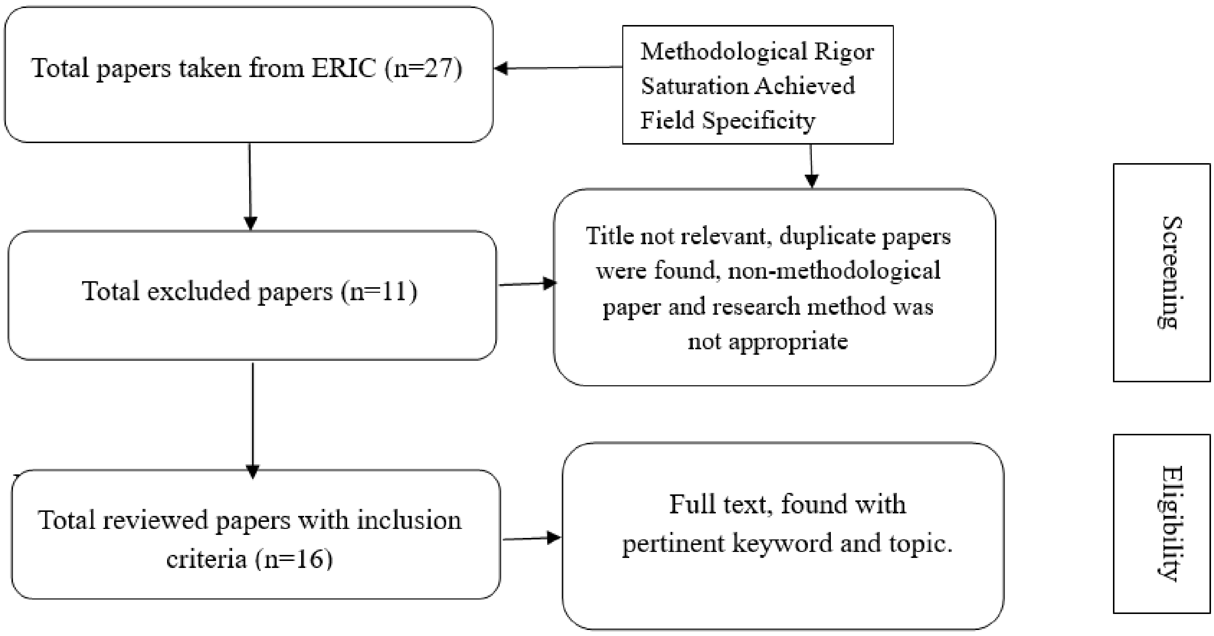

Figure 1: Flow chart to meet the inclusive criteria of the review process

2.3. Data Extraction and Synthesis

The studies were examined using the qualitative content analysis procedure, which allows systematic faithfulness to several steps. Coding and organizing the associated central messages and patterns were explained in relation to ethical considerations of STEAM practices in K-12 education. The meta-analysis centered on identifying the pedagogical models, learning outcomes, and implementation contexts in which STEAM approaches were applied (such as integration of disciplines, project-based and problem-based learning, collaborative and inquiry-based strategies and creativity and technical skills).

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Similarly, author, year published, topic, context, focus area, methodologies, and main results(s) were all systematically extracted from the 16 selected studies, organized and simplified into tables (see Table 1). This method provided a means of tracing the boundaries and breadth of research across various K–12 education systems and documented the research thoroughly. This technique also provided a basis for recognizing correlations, comparing multiple methodologies, and determining how STEAM integration is implemented across a range of education systems. The synthesis was guided by a thematic review approach, aiming to provide a comprehensive overview of the practice and use of STEAM approaches in the K-12 education setting, based on the studies' findings. By conducting such integration, the common themes emerging from literature include the concepts of creativity, teamwork, student participation, problem-solving, and interdisciplinary studies, among many others. This process of identifying the importance of the various themes is also part of the process of the thematic analysis described here.

This approach was applicable in determining common trends, important factors, and evolving best practices within the reviewed body of literature, according to the working principles involved in the qualitative meta-synthesis approach, culminating in an amalgamation of findings for purposes of forming a more encompassing image, as explained by Hansen et al. (2021). Table 1 below provides details on authorship, context, and thematic contributions for the studies analyzed following the screening and selection process.

Table 1: Analyzed Literature and its Thematic Distribution

S.N.	Author(s) & Year	Thematic Concentration	Context/s
1	Allina (2018)	Aspects of creativity, interdisciplinary learning, and the transformative experience in collaboration are all advanced in the process of integrating the arts into STEM fields	USA
2	Kim et al. (2019)	All of the collaboration, integration, and learning transformational experiences are augmented as the process of incorporating the arts into STEM fields continues	USA
3	Hsia et al. (2021)	Integrative Problem Solving in Flipped Learning Improves Creativity and Collaborative Skills	Taiwan
4	Carter et al. (2021)	Examining and contextualizing European approaches to higher education STEAM Integration in relation to fostering interdisciplinarity, creativity, and collective problem solving	Conceptual/General Context
5	Dahal (2022)	Transformative STEAM Education as a Critical, Humanizing, and Culturally Responsive Praxis	Nepal
6	Wahba et al. (2022)	The STEAM activities help cultivate student metacognitive awareness	Jordan
7	Chang et al. (2023)	The incorporation of STEAM into project-based learning to improve the creativity and computational thinking of the learners	Taiwan
8	Koirala and Neupane (2023)	STEAM-integrated curricula foster transformative learning adequately, and educational training is necessary	Nepal
9	Leavy et al. (2023)	The emerging technology in STEAM in the arts, and prioritizes STEM and 21st-century learning in education, is a basis for collaboration and streamlined intensive education	Cyprus
10	Filipe et al. (2024)	Integrated STEAM (iSTEAM) activities, digital tools, and technology foster creativity in learners and improve their problem-solving abilities	Portugal

11	Zaqiah et al. (2024)	Assessing the impact of STEAM education in fostering collaboration and creativity as part of the 21st-century skills	Indonesia
12	MF and Palennari (2024)	To determine the use of the PjBL-STEAM model, focusing on problem-solving skills	Indonesia
13	Lazarinis (2025)	The use of multilayered STEAM approaches to improve student engagement and real-world learning	Greece
14	Alfirda et al. (2025)	STEAM-based, real-world project learning enhances students' critical and problem-solving abilities	Indonesia
15	Pramudyani et al. (2025)	Play activities: teachers' understanding of STEAM influences the development of 4c skills	Indonesia
16	Behera et al. (2025)	Enhancing students' collaboration, creativity and critical thinking in STEAM learning through innovative, inquiry-based, and interdisciplinary teaching methods.	Conceptual/General Context

2.4. Analysis

This approach was applicable in determining common trends, important factors, and evolving best practices within the reviewed body of literature, according to the working principles involved in the qualitative meta-synthesis approach, culminating in an amalgamation of findings for purposes of forming a more encompassing image, as explained by Hansen et al. (2021). Table 1 below provides details on authorship, context, and thematic contributions for the studies analyzed following the screening and selection process.The meta-synthesis of 16 studies published between the years 2018 and 2025 shows that there has been a trend towards embracing integrated, project-based, arts-infused, or inquiry-based STEAM implementations with intention to cultivate 4Cs align students' skills for innovation in the 21st century, which include skills like critical thinking, collaboration, creativity, and problem-solving. Out of the total sixteen articles included in doing a screening, two articles, namely Allina (2018) and Kim, Lee, and Hwa (2019), are on promoting arts integration to foster innovation, collaboration, or transformative learning. In the same manner, Hsia et al. (2021) and Carter et al. (2021), the other two articles focus on learning enhancement through the arts, which centers on students' creativity and collaborative problem-solving. The other four included studies, Dahal (2022), Wahba et al. (2022), Chang et al. (2023), and Koirala and Neupane (2023) raised the predominantly relevant issue of STEAM approaches, widely focusing on how students think, act and engage with their world for achieving 21st century skills. The other eight articles sought to improve students' creativity, collaboration, and critical thinking in STEAM education through the use of pioneering, interdisciplinary, and inquiry-based pedagogical approaches.

Data synthesis was conducted using a systematic, multi-step process to ensure the inductive, evidence-based development of the final themes. All extracted data, particularly the key findings, observed pedagogies, and reported challenges from the sixteen included studies, were imported into ATLAS.ti 23 software. These codes and the tracing of the consistency of concepts across diverse literature were well managed through the capabilities of the software. The first textual frequency analysis is done in ATLAS.ti yielded a Keyword Cloud (Figure 2) which, for a first glance, visually confirmed core concepts of interest: 'Creativity,' 'Collaboration,' and 'Assessment.' These anchor terms came forward, reassuring that three final emergent themes were well placed: Integrated Pedagogies, Enhanced Outcomes, and Assessment Challenges.

3. Results

This is a consolidation of results from sixteen studies related to STEAM education, grouped under three themes. The first grouping is centered around integrated learning practices, particularly Project-Based Learning and Design Thinking, as they implement STEAM concepts. The second grouping shows that these practices improve creativity, collaboration, metacognition, and conceptual knowledge, where Arts disciplines serve as essential avenues for creative development. The final grouping details challenges of implementation, such as teacher training, availability of resources, as well as assessing competency.

3.1. Integrated and Inquiry-Driven Pedagogies

This theme meets the first research question, since it illustrates how the foundational works of STEAM education theory are actually applied at the K-12 level. According to research, STEAM is not a term about discipline but rather a combination of pupil-centered instructional strategies which shake the traditional disciplinarian approach to education. The effective shake-up of such instructional strategies has their basis in PBL and Design Thinking frameworks and pedagogy that structure the simultaneous integration of several domains. The same framework also guides the student through an authentic, inquiry-centered experience.

3.2. Project-Based Learning and Design Thinking

The application of the principles of STEAM education can be most readily facilitated by the application of practical projects that increase the efficacy of PBL as the most fundamental pedagogical thrust (Chang et al., 2023). In this approach to the application and execution of science education and learning experiences included under the realm of STEAM education, the letter 'A' which represents the 'Arts' can be readily applied as the hinge connecting the learning application and execution. Therefore, for example, research demonstrated that the application of both 'Design Thinking' and 'Project-Based Learning' models together as 'DT-PBL' enabled students to effectively discover the problem sets in the domain of engineering design and the application of technology with the application of artistic visualization and practice in the arts as MF & Palennari (2024) showed in their research. There would therefore be an application aligned with this approach so that students not only gain knowledge but are able to practice the entire gamut of the creative problem-solving process that starts with ideation and ends with testing and refining outcomes.

It has a different set of activity details. However, they all have a core set, which involves an integrated task requiring knowledge across various domains to accomplish it. Wahba et al. (2022) discovered that primary-stage learners who participated in structured STEAM activity lessons demonstrated enhanced understanding of the subject matter after applying mathematical concepts to a concrete problem. The action itself, once learned, now becomes a function for learning, emphasizing exploration across different domains (Allina, 2018). Their popularity signifies a paradigm shift away from a learner-centered delivery model, which describes the STEAM paradigm itself.

These practices employed in studies are summarized in Table 2 to demonstrate the practical approaches. The evidence suggests that PBL and DT are the key approaches across the K-12 spectrum in the translation of STEAM theory into practice. Each of these structured models also gives students the opportunity to work on real interdisciplinary projects and problems to apply problem-solving in the real world. Further, the incorporation of numerous fields of knowledge promotes creativity, progressive design, and experimentation. In conclusion, the broad use of these approaches across diverse settings would indicate that these strategies are encouraging a global pedagogical shift towards more student-centered and STEAM inquiry-based implementation.

Table 2: Dominant Pedagogical Models in Steam Implementation

Pedagogical Model	Description of Application in STEAM	Representative Studies
Project-Based Learning (PBL)	Students engage with large-scale, sophisticated challenges, working with a combination of content areas from STEM + Art to create a final product or solution	Chang et al. (2023) ; MF & Palennari (2024) ; Wahba et al. (2022)
Design Thinking (DT)	A human-centered, iterative process (Empathise, Define, Ideate, Prototype, Test) used to structure creative problem-solving and engineering tasks, often integrating Arts for visualisation and communication.	Hsia et al. (2021) ; Koirala & Neupane (2023)
Interdisciplinary Task Structure	Learning from two or more subjects in integrated units is also called interdisciplinary learning. This approach also promotes interdisciplinary learning	Lazarinis et al. (2025) ; Leavy et al. (2023)
Technology-Enhanced Learning	Employing architectural data, using digital technologies, coding, and robotics, and creative computational thinking to develop constructs, model, and simulate processes while refining data analysis and/or artistic creation	Carter et al. (2021) ; Zhai & Chen (2024)

3.3. Enhanced Creativity, Collaboration and Metacognition

The incorporation of STEAM techniques improves student recruitment and, in a statistically significant manner, enhances performance across the non-cognitive and affective domains necessary for learning and solving higher-order, complex problems. Recent studies report greater attentional focus, sustained for more extended periods, and a greater willingness to undertake more difficult interdisciplinary tasks involving manual skills. These methods also help develop the necessary creativity, collaboration, and determination for the 21st century by engaging in STEAM-based learning activities. This demonstrates that STEAM also helps students develop the skills required to perform various tasks in a more flexible and innovative manner.

3.4. Measurable Growth in Creativity and Collaboration

Students' creativity has benefited most and thus been most supported by STEAM education. Certain artistic frameworks and techniques were found to improve one's ability to create. These frameworks and techniques included drawing, doing visualizations, and iterating designs to improve one's work (Filipe et al., 2024). Students engaged in STEAM activities reported increases in the ability to create with fluidity, smooth, efficient shifts in thought, and the ability to generate original ideas (Hsia et al., 2021). This suggested that the Arts component provides novel pathways for idea generation and divergent thinking. Furthermore, because most STEAM activities are structured as collaborative projects, studies consistently found increases in collaborative work, communication, and shared critical thinking as well as problem solving skills. The need for students to balance artistic ideas and engineering limitations within a group develops their collaborative competencies (Wahba et al., 2022).

3.5. Developing Metacognition and Conceptual Understanding

The inquiry-driven nature of STEAM develops creativity and advanced cognitive skills in students (Table 3). Wahba et al. (2022) observed that students in STEAM programs demonstrated greater self-monitoring and strategic thinking when solving complex problems. This allowed them to know their own conceptual understanding and adjust their approaches iteratively. This also leads to a deeper conceptual understanding of STEM subjects because the Arts provide a multisensory channel for expressing and understanding abstract scientific and mathematical principles (Allina, 2018). The creative need to communicate or visualise a solution ultimately fosters the student's easier understanding of the technical content.

Table 3: Different Skills and their outcomes

21st-Century Skill	Observed Outcome	Representative Studies
Creativity	Increased fluency, flexibility, and originality in problem-solving and design outputs.	Hsia et al. (2021) ; Filipe et al. (2024)
Collaboration	Improved teamwork, communication, and negotiation skills during group project execution.	MF & Palennari (2024) ; Wahba et al. (2022)
Metacognition	Improved capacity to contemplate, oversee, and control one's self-regulated thinking and learning at the conceptual level.	Wahba et al. (2022)
Conceptual Understanding	Applicable craftwork representation that is both artistic and tactile will yield greater mastery and understanding of pertinent mathematics and science content.	Allina (2018); Lazarinis et al. (2025)

3.6. Implementation of Gaps and Assessment Challenges

Although literature details the growing pedagogical opportunities for STEAM, fundamental barriers remain to its sustainable and equitable deployment. These are the challenges in the third theme and primarily concern assessment and the advancement of creativity, as discussed in the second research question. There is limited institutional commitment, and insufficient teacher training and in-service professional development opportunities makes it very challenging for educators to adopt the STEAM approach confidently. Furthermore, the absence of comprehensive assessment frameworks for creativity, cross-disciplinary collaboration, and design thinking makes it very difficult to integrate STEAM in the classroom in a meaningful way.

3.7. Limited Teacher Preparedness and Resource Constraints

The need to design Continuous Professional Development (PD) programs to support teachers has been emphasized in studies conducted in different parts of the world. The studies report limited pedagogical content knowledge, a barrier to effective STEAM integration (Koirala & Neupane, 2023; Behera et al., 2025). This leads to extremely surface-level engagement with STEAM, where the "Arts" are not given due acknowledgement as a legitimate and important component of the strategy and inquiry process, and are regarded as purely marginal decorations. The required infrastructural and material resources are often scarce- outdated technology, insufficient digital tools, and a lack of specialized materials. The projects involved are often complex STEAM projects and long-term, which makes them difficult to implement due to the tightness of most curricular timelines (Koirala & Neupane, 2023).

3.8. The Challenge of Authentic Assessment

The literature identifies the assessment of 21st-century skills developed through STEAM as one of the most important and unresolved challenges (Table 4). Contemporary methods of summative testing are not applicable to measure growth in creativity, collaboration, and metacognitive awareness (Carter et al., 2021). It is difficult to develop authentic, reliable, and valid rubrics that can objectively assess the design thinking method, the originality of creative products, and the quality of collaborative effort (Leavy et al., 2023). This application gap fuels the continued use of conventional, standardized testing, which indirectly discourages the application of time-consuming STEAM approaches, thus posing a great threat to the actualization of the potential inherent in this paradigm.

Table 4: Challenges and their impact on STEAM Pratice

Key Implementation Challenge	Impact on STEAM Practice	Representative Studies
Inadequate Teacher Training/PD	Leads to superficial or non-existent integration of the Arts ('A'); teachers revert to familiar, siloed instruction.	Koirala & Neupane (2023) ; Behera et al. (2025)
Resource & Infrastructure Gaps	Limits the ability to execute hands-on, technology-enhanced, or material-intensive projects, constraining pedagogical models (e.g., PBL).	Koirala & Neupane (2023)
Absence of Authentic Assessment	Traditional assessment tools fail to measure complex skills (creativity, collaboration), discouraging rigorous STEAM implementation.	Carter et al. (2021) ; Leavy et al. (2023)

3.9. Data Synthesis and Findings from Tool-Assisted Analysis

The analysis was done using the ATLAS.ti 23 computer-aided analysis software on the 16 documents. The massive number of texts selected from the studies made it imperative to use computer-aided analysis software in coding the texts and searching for possible patterns that might emerge. The results, teaching practices, and problems in the core texts were coded in two cycles, specifically open coding and focused coding. The focused coding process further grouped the initial codes into more general codes.

The data analysis led to the generation of a word cloud that provided a visual representation of the data by using common terms from all documents. The terms used in creating the word cloud included 'Creativity,' 'Collaboration,' 'Assessment,' 'Project-Based Learning,' and 'Design Thinking.' This data provided insight into contemporary discussions that are currently taking place in terms of STEAM extension. This data visualization also satisfied the requirement of standard thematic analysis, allowing further explanation of themes such as Integrated Pedagogies, Enhanced Outcomes, and challenges of assessment.

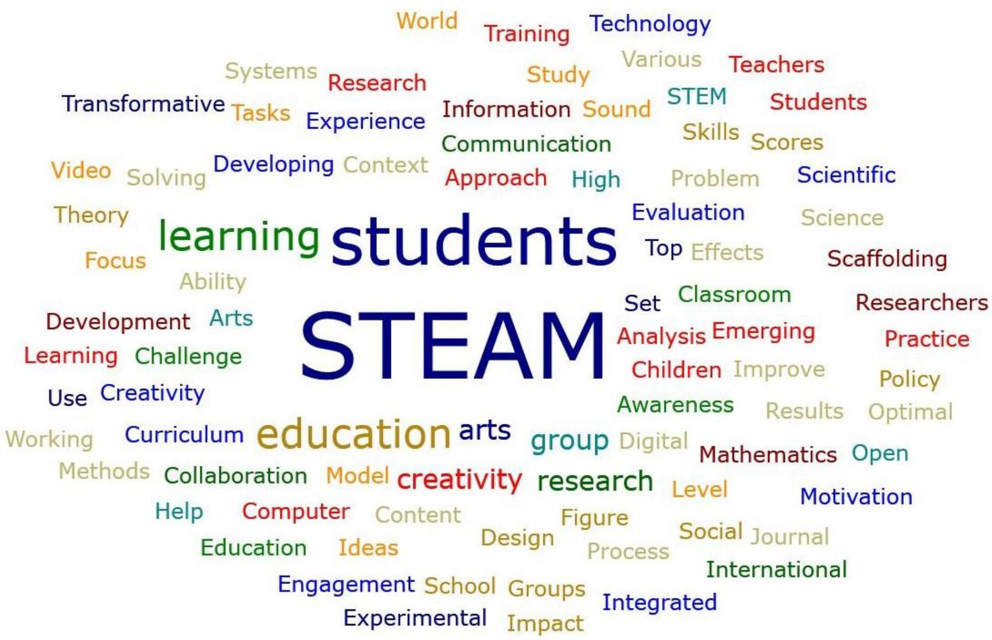

Figure 2: Word cloud generated using ATLAS ti

4. Discussion

The main objective of this literature review was to collect and synthesize current knowledge available for the implementation of STEAM in K-12, particularly targeting theories and difficulties connected with assessment and development of skills for this concept. The results, divided into three primary themes, provide an answer to each of the research questions. This supports the pedagogical validity of the STEAM approach and also features important obstacles to its widespread, sustainable adoption. The primary research question was sought to analyze the implementation of STEAM in K-12 education systems in relation to theory. Evidence demonstrates that STEAM is grounded in constructivist and socio-cultural learning theories. This is operationalised through PBL and DT (Sunzuma et al., 2025).

The reviewed theories show that PBL and DT foster interdisciplinary learning. PBL offers students the opportunity to apply knowledge from various subjects to real-world scenarios. Through a systematic, iterative process, DT integrates the Arts into human-centered design (Eswaran, 2024; Chang et al., 2023; Atman Uslu, 2025). This integration of the Arts is what distinguishes STEAM from the traditional STEM model. Its purpose is two-fold: to visualize and communicate, and to stimulate more creative constructions. So, within Design Thinking and Project-Based Learning, the Arts furnish students with needed non-verbal means to model the complexities of science and mathematics (Norman & Zoncita, 2023; Khan et al., 2023). Students in STEAM classrooms, for instance, use prototyping, sketching, and thoughtful arrangement to communicate complex technical concepts, thus making them easier to understand (MF & Palennari, 2024). This step of visualization is crucial in the design process.

Furthermore, the Boy (2013) & Burnard et al. (2022) argue that the so-called technical domains perform poorly in fostering mental, intellectual, and even creative cultivation through the Arts in the domains of instruction. This is of great importance because the Arts educate students to tackle real world challenges that require high-level rational and a multifaceted, non-linear approach. In addressing cognitive barriers, students are provided with alternative ways of framing and analytical reasoning through the incorporation of the design and the artistic elements. According to Allina, students are allowed to develop hypotheses, which will enable them to come up with different solutions rather than sticking to a linear way of doing things. This is essential since students are able to develop both the ability to be creative, which is vital in learning, and resilience.

Additionally, the Arts also extend engagement through the further clarification of scientific and mathematical theories and the means by which the abstract can be more clearly represented. These modes of representation can be seen as a bridge between the abstract and the application, where the student can better connect to the concept. It is the integration of the principles of learning through experience and the modes of PBL and the essential ‘A’ that make STEAM education so powerful. The integration of these teaching modes, where the depth of the disciplines, is further broadened through the addition of the entire skillset needed to survive in the rapidly paced innovative world that surrounds us.

Learning results, correlations involving assessments, and difficulties involving creativity and collaboration in learning were covered. On the other hand, findings can be considered a double-edged sword. Learning results lead to the addition of more skills for the student, yet difficulties exist in relation to the execution of STEAM pedagogy. The execution of STEAM in instructional practice through pedagogy as a systematic process leads to a significant number of results involving enhanced performance in terms of creativity, collaboration, and metacognition. Results involving creativity include flexibility and originality, while results for metacognition support self-regulation and reflection. On the other hand, results for collaboration show different working parts involving an aspect of teamwork and negotiations (Hsia et al., 2021; Wahba et al., 2022). The result demonstrate the effectiveness of the STEAM approach in ensuring the development of skills for the 21st century. Nevertheless, the literature review identifies some of the contributing factors for the poor adoption of the STEAM approach in the instructional process. The most inhibiting factors include the deficiency of qualified personnel delivering the interdisciplinary approach (Koirala & Neupane, 2023; Behera et al., 2025) and the insufficient development of the complex assessment framework to evaluate the skills (Carter et al., 2021; Leavy et al., 2023). Indeed, the STEAM approach has the best teaching and learning practices but insufficient teaching structure (Ahmed & Opoku, 2022; Goodyear, 2022).

Additional arts education will support students in the enhancement of analytical skills in contemporary education. From research, the training of the Arts had positive outcomes, including improving the students' creativity and collaboration skills, particularly in the aspects of fluency, flexibility, and originality (Filipe et al., 2024; Hsia et al., 2021). Moreover, the enhancement of schoolchildren's reflection skills and comprehension of pivotal concepts denotes that the proposal to integrate STEAM has positive features and will not just keep the students occupied but will also help learners develop complex skills regarding deep reflection (Wahba et al., 2022). STEAM goes beyond shallow learning by helping students reflect on their knowledge, reframe key concepts, and articulate sophisticated scientific ideas through artistic and innovative methods. Students better understand ideas as they interact with content in a variety of ways and through multiple senses. Students' long-term retention and mastery of the concepts are also enhanced when they are taught to express technical ideas in the Arts creatively. STEAM also helps students think more deeply and understand discipline more effectively by designing a facilitative learning environment that provides them to express their ideas in multiple ways.

The literature has shown clear benefits of STEAM education and describes the challenges and gaps in implementation that can affect the ability to sustain and effectively implement this approach in the long term. Inadequate teacher training across various fields leads not to under-collaboration but rather to superficial, “added-on” integrations of the Arts (Koirala & Neupane, 2023). The main challenge in implementation is the disparity between conventional evaluation and the heterogeneous results associated with creativity, collaboration and STEAM.

This review holds significance against the backdrop of the examination-oriented Nepali educational system (Pant et al., 2024). DT-PBL models propose educational structures to transition toward competency-based and experiential learning. However, challenges remain in terms of avoiding superficial STEAM implementation in Nepal. Issues that need urgent engagement include teacher training and continuous professional development, educational resource frameworks, and the design of innovative assessment methodologies. Hence, it is suggested that targeted professional development on interdisciplinary co-teaching and authentic assessment is provided to successfully reform the education system.

5. Conclusion

This thematic review systematically analyzed contemporary literature of STEAM education in K-12 contexts to highlight pedagogical foundations and their implementation challenges. The results confirm that fundamental principles of STEAM are strongly converted into action through Project-Based Learning and Design Thinking. DT-PBL brings the Arts to the forefront as a means of unique visualization and problem-solving. The review further confirms that the integrated approaches do indeed enhance creativity, collaboration, and cognitive awareness at a higher level.

However, the study also found that systemic implementation gaps are among the most critical challenges to the long-term success of the STEAM paradigm. The immediate challenge is interdisciplinary teacher capacity-building. Another challenging aspect is the development of genuine assessment instruments that can effectively capture advanced process skills like creativity and metacognition. Results obtained from this review indicate that if teacher capacity and innovative approaches for assessment reform are not invested in, STEAM education will essentially become an isolated high-impact project instead of a curricular reform.

There must be empirical research done on the development and construction of common and effective rubrics for the study of creative fluency, process quality for collaboration, and metacognitive development in interdisciplinary STEAM activities. There must be research carried out on the feasibility and efficiency of co-teaching approaches for the arts and science educators as the prime method for the success and integration of the curriculum. There must be qualitative research conducted on the challenges faced by the cultures and resources available in environments such as Nepal and the efficiency and feasibility associated with inexpensive STEAM models.

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